# Teaching Introductory Statistics in the Social & Behavioral Sciences Approach & Rationale

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***Almost a century ago the noted English author H.G. Wells said, "Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write."***

## ABSTRACT

The teaching and learning of introductory statistics in the behavioral sciences continues to generate much debate on content and pedagogy amidst on-going reform. Facilitating change where appropriate also necessitates an understanding of instructors' motivation for their approach. This pilot study explored approaches to teaching introductory statistics, and instructors' rationale for their approach. Emphasis on concept, calculation and both were reported by 30 (70%), 4 (9%) and 9 (21%) respectively. Teaching approaches were characterized as mechanistic, pragmatic and holistic. These findings can be used to design subgroup-specific interventions for current and prospective instructors of statistics.

**Key Words:** Introductory, Statistics, Concept, Reform, Psychology, Behavioral

## INTRODUCTION

Formalization of statistics education dates back to over 150 years ago with the work of the Royal Statistical Society and subsequently the American Statistical Association (ASA). Another organization, the International Statistical Institute (ISI) was established in 1885, and it was the founding of the Committee on Statistical Education within the ISI in 1948 that initiated serious and focused dialogue on the training needs of the discipline, and research in statistics education (Vere-Jones, 1995 & Ottaviani, 1999). The ISI-Committee on Statistical Education (and its successor, the International Association of Statistical Education – IASE, established in 1991) emerged as the leader in this regard with a broad international focus whereas the ASA took the charge in the USA. Over the last twenty years, the academic community, primarily in the USA, has witnessed active reform in undergraduate statistics education, in close association with the ASA, the Mathematical Association of America (MAA) and the National Science Foundation (NSF). Specifically, there is a well-defined movement focused on reform in the teaching and learning of introductory statistics (Cobb, 1993).

Introductory courses in any discipline are intended to provide students with exposure to the fundamentals of the field, and serve as a basis for pursuing advanced courses in that or related fields. Such courses can influence students' perceptions of and attitudes toward the discipline, and hence to a large extent, determine whether they choose to pursue the field or go beyond the first course. Above all, course content and instructional methodology will affect the quality of knowledge and skills acquired. (Moore, 1988; Garfield et al., 2002).

In this regard, statistics is unique, as described by Cobb and Moore (1997): "Statistics is a methodological discipline. It exists not for itself but rather to offer to other fields of study a coherent set of ideas and tools for dealing with data." In almost every discipline, the ability to critically evaluate research findings (often expressed with statistical jargon and notation) is recognized as an essential core skill (Giesbrecht, 1996) especially for college students interested in becoming practitioners (Buche & Glover, 1988). Among such disciplines, statistics is almost universally considered an important and compulsory component of the psychology major (Morgan, 1999; Gordon, 1995). As Mosteller (1989) notes, statistics is an important tool for analyzing the "uncertainties and complexities of life and society."

There is consensus among statistics educators that introductory statistics courses should follow a general education framework, and be an integral part of the post-secondary curriculum (Cobb, 1992; Hogg, 1992). Toward this end, and amidst multiple compelling reports of mathematics anxiety, fear, lack of interest and frustration manifested by students, (Garfield & Ahlgren, 1988; Dallal, 1990; Perney & Ravid, 1991; Gal & Ginsburg, 1994), the ongoing statistics reform movement has emphasized a shift from the predominantly mathematical and theoretical approach to teaching introductory statistics (Moore, 1993) to a more concept-based approach aimed at fostering statistical thinking and literacy through quantitative reasoning (Garfield, 2002; Chance, 2002).

## Quantitative Reasoning and the Concept-Based Approach

In general, the objective of quantitative reasoning is to facilitate students to become informed consumers of statistical information (Chance, 2002) by addressing conceptual issues about data such as distribution, center, spread, association, uncertainty, randomness and sampling (Garfield, 2002). In particular, Moore (1990) argues that the key to statistical reasoning is facilitating the student to recognize and appreciate the omnipresence of variation and understand how such variation is quantified and explained. Critical to this approach is an understanding of the context from which the data emerged and to which the findings will be applied (Chance, 2002). This concept-based strategy seems premised largely on the theory of constructivism which evolved from the works of John Dewey, Jean Piaget and L. S. Vygotsky, who characterized learning as "experiencing the material"(Steinhorst & Keeler, 1995).

Constructivism in general, and its application to the teaching of statistics purport that students construct new knowledge and meaning by linking and relating new experience and information to previous knowledge (Cobb, 1994; Von Glasersfeld, 1987). In this regard the emphasis is on creating active learning environments (Garfield, 1993) which address real world problems with real world data, facilitating learning which is deep and meaningful rather than rote. Consistent with this approach, Hogg (1991) has suggested that statistics at the introductory level should be emphasized as a tool of research by addressing the formulation of appropriate questions, effective data collection, interpreting, summarizing and presenting the data with attention to the limitations of statistical inferences. The author notes that "good statistics is not equated with mathematical rigor or purity, but is more closely associated with careful thinking."

## The Reform – Strategies and Challenges

The compelling need for reform in the teaching and learning of introductory statistics at the undergraduate level was noted almost three decades ago, and can be largely attributed to contemporary widespread reports from instructors that non-statistics majors were lacking grossly in their understanding of basic statistical concepts and ability to solve applied statistical problems (Garfield, 1988 based on the works of Urquhart, 1971; Kalton, 1973; Duchastel, 1974; Jolliffe, 1976). The statistics reform movement in the USA was formalized around 1990 (Cobb, 1993), and to date its work can be characterized as an iterative and inductive process with multiple strategies and different emphases aimed at promoting statistical thinking and literacy by emphasizing concepts and applications rather than calculations and formulae (Moore, 1998; Cobb, 1992). Reform strategies have addressed course content, pedagogy, assessment, and use of technology (Garfield, 2003; Garfield, 2000; Hawkins, 1996) with attention to the cognitive (delMas, 2002) and affective domains of learning (Roiter & Petocz, 1996; Garfield et al., 1999). These strategies have been guided primarily by the theory of constructivism (delMas et al., 1998).

The ongoing reform has generated an abundance of literature (anecdotal information, case studies, cross-sectional studies and to a much lesser and almost negligible extent, longitudinal and quasi experimental studies). While some articles have claimed success with selected statistical topics (Hassad, 2002), many have detailed continued difficulties with the teaching and learning of introductory statistics in general. In particular, leading statistics educators have noted that: "No one has yet demonstrated that a particular set of teaching techniques or materials will lead to the desired outcomes" (Garfield et al., 2002). Indeed, there remains much ambiguity as to what constitutes statistical thinking (the desired outcome), and how it should be facilitated and measured from the teaching and assessment perspectives (Garfield et al., 2002, delMas, 2002; Chance, 2002). Wild and Pfannkuch (1999) have implied that the concept of "statistical thinking" is elusive and efforts in this regard might be speculative at best.

The most recent comprehensive evaluation of the impact of statistics reform, a project of the National Science Foundation (Garfield, 2000) identified a high level of selected pedagogical practices (characterized as active learning strategies) which have been hypothesized as necessary determinants and facilitators of statistical thinking. What remains to be investigated is if such pedagogical strategies lead to the desired outcomes. Amidst authoritative calls for research to investigate how to help students develop statistical thinking, and how to assess whether or not they possess this ability, the role of the instructor has emerged as a core and priority focus for research (Chance & Garfield, 2002).

Candace Schau, a pioneer statistics educator has proposed a preliminary comprehensive model with emphasis on the instructor (Garfield et al., 2002). This model is comparable to an earlier general model proposed by Biggs (1989) which utilizes the "systems" approach to understanding the relationship among the myriad of factors which impact teaching and learning. Biggs' model posits that there are presage factors (faculty and student characteristics), process factors (students' perceptions of the teaching-learning context and their approaches to learning) and product factors (learning outcomes with attention to both quantity and quality) which operate in the teaching and learning contexts. Both models feature faculty characteristics/preparation, a domain which has been neglected by the introductory statistics reform movement and researchers (Rossman & Chance, 2002). Of special note is that Schau's model compared to Biggs' model appears to give greater importance to students' attitudes and beliefs. In particular, Schau's model addresses attitudes and beliefs as both input and outcome factors of the teaching-learning process which appears consistent with achieving statistical thinking.

Additionally, Schau, Dauphinee and Vecchio (1992) identified teacher characteristics as a general theme in students' explanations of their feelings regarding mathematics and statistics. The critical importance of faculty preparation and other characteristics is further underscored in the words of Carl Morris (1995) on introductory statistics education reform: "Can the needed changes be made? I am pessimistic about this. It is awfully hard to change, because to do so requires performing surgery on ourselves [academicians]. And that hurts."

## Objective

It seems quite plausible that if we are seeking to have students achieve internal representation of concepts through deep learning, then it is imperative that we first seek to foster among our instructors internalization of the value of the strategies being promoted for reform (Bell, 2001). Therefore, in order to determine the level of preparedness of instructors consistent with reform recommendations, the objective of this study was to ascertain instructor's emphasis **(concept versus calculation)** in the teaching of introductory statistics in the social and behavioral sciences, and their rationale for the emphasis.

## METHODOLOGY

This internet-based cross-sectional study addressed the question: Should we emphasize calculation or concept in the teaching of introductory statistics in the behavioral sciences at the undergraduate level? This question was circulated on the 10th December, 2002 to members of ALLSTAT (a UK-based worldwide email broadcast for the statistical community) and SRMSNET@LISTSERV.UMD.EDU (the email list of the Survey Research Methods Section of the ASA – American Statistical Association). The survey was closed two days later (12th December) after forty-three (43) responses from unique email addresses were received. To reduce possible bias from cross-dialogue, members of these email lists were encouraged to send responses directly to the researcher.

In the final analysis, there were 3 (three) response categories for the stated question.

1. Emphasize concept.
2. Emphasize calculation.
3. Both must be emphasized (as concept and calculation are not separate elements). This third category was formulated after examining the responses. Further, 37 (86%) respondents supplied open-ended text to support their teaching emphasis. Most of these responses were well structured and detailed making them amenable to thematic analysis. The emerging themes were used to characterize the teaching approaches.

## RESULTS

**Table 1:** Should we emphasize calculation or concept in the teaching of introductory statistics in the behavioral sciences?

| Distribution of Responses (N = 43) | | | | |
|---|---|---|---|---|
| **Group** | **Concept** | **Calculation** | **Both** | **Total** |
| ALLSTAT (UK list) | 12(70%) | 3(17%) | 2(12%) | 17(100%) |
| ASA (USA list) | 18(69%) | 1(4%) | 7(27%) | 26(100%) |
| Total | 30(70%) | 4(9%) | 9(21%) | 43(100%) |

**Table 2:** Summary of qualitative reports provided by respondents to justify their teaching emphasis

| Motivation (Rationale) | Emphasis | N | % |
|---|---|---|---|
| **1.** Students will be consumers of statistical information rather than producers. | Concept | 7 | 19 |
| **2.** Software is available for computation. | Concept | 5 | 14 |
| **3.** Software is available for computation. Focusing on concepts allows for selecting the appropriate test and interpreting the outcome. | Concept | 6 | 16 |
| **4.** Concepts are lasting, should precede calculations, allow for clarity and real-world connection, and address numeracy skills and fear. | Concept | 8 | 22 |
| **5.** Leads to better grasp of the subject as it is rule-based. | Calculation | 3 | 8 |
| **6.** Must consider how students learn. They may need calculation and problem-solving to understand numeric derivation and reinforce concepts. The "right' mix depends on the next step in students' education | Both Concept and Calculation | 8 | 22 |

The information contained in Table 2 was used to characterize teaching approach **(Figure 1)**. In particular, attention was given to reported motivation (explicit and implicit). Subgroups 2 and 5 were characterized as **mechanistic** given their pre-occupation with calculation, formulae and technology. These instructors also demonstrated misunderstanding of the concept-based approach. Subgroups 1 and 3 were characterized as **pragmatic** based on their reported use and understanding of the concept-based approach. These instructors seem to allow the teaching process to be defined and influenced by practical outcomes and applications. Finally, subgroups 4 and 6 were characterized as **holistic**, as in addition to the characteristics of the pragmatic approach, these instructors referred to learning theory, learning styles, student characteristics and education goals.

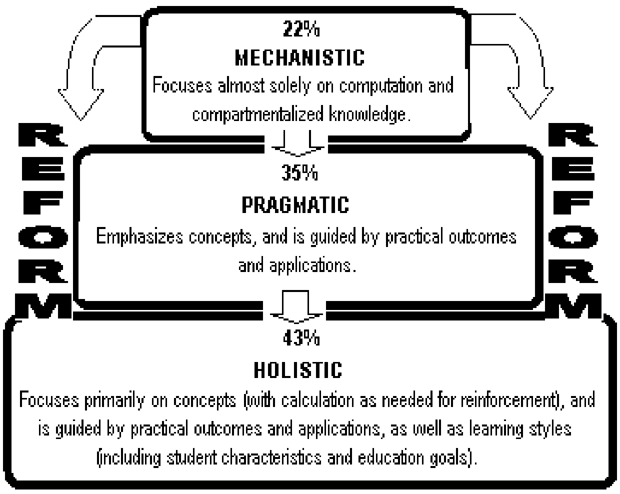


**Figure 1: Characterization of Teaching Approaches**

## DISCUSSION

The findings from this mini internet survey seem plausible, and in general, are consistent with expert opinions and the research literature, in particular, the most recent comprehensive evaluation of the impact of statistics reform (Garfiled, 2000). The results suggest a high level of awareness/acceptance of the concept-based approach which is considered the core strategy for reform in the teaching of introductory statistics. It must be noted that the promotion of this strategy is premised on the assumption that it will lead to statistical thinking/literacy. Albeit the concept-based approach is plausible in this regard (based on its multi-theoretical foundation), large-scale scientific research (experimental and longitudinal) is required to determine whether it is causally or directly related to statistical thinking. Even more important at this stage, is the need to establish what constitutes a valid concept-based approach, so that standardized methods can be used resulting in more meaningful research data.

Indeed, there is some concern that there is a sub-group of instructors who apparently do not understand how to operationalize the concept-based approach yet claim that they do so (Table #2, row # 2). These instructors appear to possess the simplistic view that the mere presence of computers now makes the concept-based approach possible, as if the absence of computers does not allow for this. In this regard, Hawkins (1996) notes that teaching with or without computers requires the same kind of planning and understanding about how students learn and how best to teach them. Hawkins further notes that effective teaching requires empirical evidence about materials and methods and how to integrate them in the overall teaching process.

This subgroup views concepts and technology (use of computers) as mutually exclusive elements of the teaching-learning process. Closely akin to this group are those who feel that the emphasis on teaching should be on calculations and formulae. These two subgroups of instructors can be characterized as mechanistic in their approach, that is, teaching in an abstract manner disconnected from real-world context and applications. Further, they conform "to the way statistics courses have traditionally been taught: with a focus on computation, skills, and compartmentalized knowledge"(Garfiled et al., 2002). Such teaching behaviors are clearly counter-productive to the overall goal of the statistics reform movement. This mechanistic approach seems to be fueled by a predominant focus on technology (use of computers) rather than pedagogy (Garfield, 2000; Hassad 2002).

A considerable majority (78%) of the respondents seem to have appropriately internalized (to varying degrees) the concept-based approach. Specifically, there are those who according to their reports are guided by practical applications and outcomes. Their approach appears consistent with the concept of cognitive apprenticeship, which emphasizes authentic activities aimed at reflecting the ways in which statistical information is generated and used in practice (Singer & Willett, 1993). Above all, these instructors focus on preparing students to become consumers rather than producers of statistical information, an approach that can be characterized as pragmatic. And then there are those who in addition to the foregoing approach, give consideration to learning theories, learning styles, other student characteristics and education goals. This approach is therefore defined as holistic.

### Conclusions and Recommendations

Statistics education reform ought to give greater importance to the instructor with attention to theories of change and behavioral modification. We must seek to promote teaching behaviors conducive to desired learning outcomes. This process should be facilitated in a focused and meaningful way, hence barriers and enhancing factors must be identified so that best practices can be defined, and targeted interventions formulated. It is well established that the difficulties encountered by students have been attributed primarily to the preparation and training of their instructors, in particular, statistics versus mathematics (Moore, 1993; Cobb & Moore, 1997; Garfield et al., 2002). However, the statistics reform movement has adopted a "Cinderella" approach to exploring what qualities (especially the affective domain) have been engendered by instructors' preparation and training, and the impact of these characteristics on the teaching-learning process. Research priorities at this stage should focus on ascertaining faculty attitudes and beliefs associated with the teaching and learning of introductory statistics, and determine (through large scale experimental and longitudinal designs) if there is a causal or direct relationship between concept-based teaching and statistical thinking/literacy. The reform movement should also encourage qualitative research approaches such as action research with emphasis on interaction analysis. In a follow-up study, this researcher plans to explore the development of a scale to measure **f**aculty **a**ttitudes **t**oward **s**tatistics (FATS).

These findings must be considered in light of the following. Although this is a cross-sectional study, the objective was to ascertain teaching emphasis (and motivation), which reflects a strategy consciously adopted over time. Therefore, such reports can be reasonably considered to be robust and reliable characterizations of teaching approaches. Further, the professional nature of these email distribution lists (both requiring membership) along with responses from email addresses linked to serious-minded academic and professional organizations lend credibility to the identity and self-reports of the participants. Coding and interpretation of data were performed by this researcher who currently teaches introductory statistics in the social and behavioral sciences.

The number of eligible participants in each group was not known hence an effective response rate is not reported, and bias in this regard must be considered. While the sample is relatively small, and not known to be representative of any defined group of instructors (which limits the external validity of these results), the reported teaching emphasis and emerging characterizations are plausible and reflect the thematic variation in the literature (Garfield, 2002). Above all, this study provides actionable characterizations of teaching approaches, which give much utility to these data, especially with regard to designing subgroup-specific training interventions for current and prospective instructors of introductory statistics.

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